

vi. Corrector Magnets

Corrector/trim magnets will be provided at each quadrupole in the arcs, as well as in the insertions (except at Q1 whose corrector is attached to Q2) to compensate for systematic and random errors of the magnets and to control various beam dynamic properties as discussed in the Lattice and Beam Dynamics section.

The correctors have the same aperture as their quadrupoles implying the count of 420 standard-aperture (i.e. 8 cm) correctors and 72 large aperture (i.e. 13 cm) correctors.

Standard Aperture Correctors

The 8 cm correctors are nominally 0.5 m in effective length and are an integral part of the CQS package. They contain either four multipole elements (132 per ring) or a lone dipole element (78 per ring). The following 8 cm quadrupole-corrector combinations are required for the two rings

- b_0, b_1, b_3, b_4 @ 96 QF
- b_0, a_1, b_3, b_4 @ 36 QF
- a_0, a_1, b_3, b_4 @ 132 QD
- b_0 @ 78 QF
- a_0 @ 78 QD

The dipole correctors correct the closed orbit error resulting primarily from random dipole rotational errors and quadrupole misalignments around the ring, necessitating individual current control in each corrector. For this reason, a design using relatively low current has been adopted; this reduces the size of the electrical bus work, power supplies and heat leaks in cryogenic current leads. The normal quadrupoles are used for the gamma-transition jump. The skew quadrupole correctors correct: 1) the effect of random skew quadrupole errors in the dipole, an effect which can be reduced and perhaps eliminated by a shuffling/sorting procedure, and 2) random installation errors in the quadrupoles. The decapole correctors compensate for dipole iron saturation effects. The octupole correctors are used for the correction of second order chromaticity effects; b_4 will remain initially without power supplies.

Figure 1-10 shows a cross-section of the four-element arc corrector magnet (the "cold mass"), and Fig. 1-11 shows the cross-section in greater detail. The magnet utilizes a cold stainless steel beam tube of ~69 mm inner diameter common to the CQS assembly. In radially increasing order, the coil structures are decapole, octupole, quadrupole, and dipole coils, respectively. Each of the inner three structures consist of a double layer of racetrack coils wound with superconducting

wire, with one coil per pole. The outermost winding, the dipole, has three double layers of superconducting wire arranged to minimize field harmonics. Each double layer is wound on a flat, flexible substrate using the specially

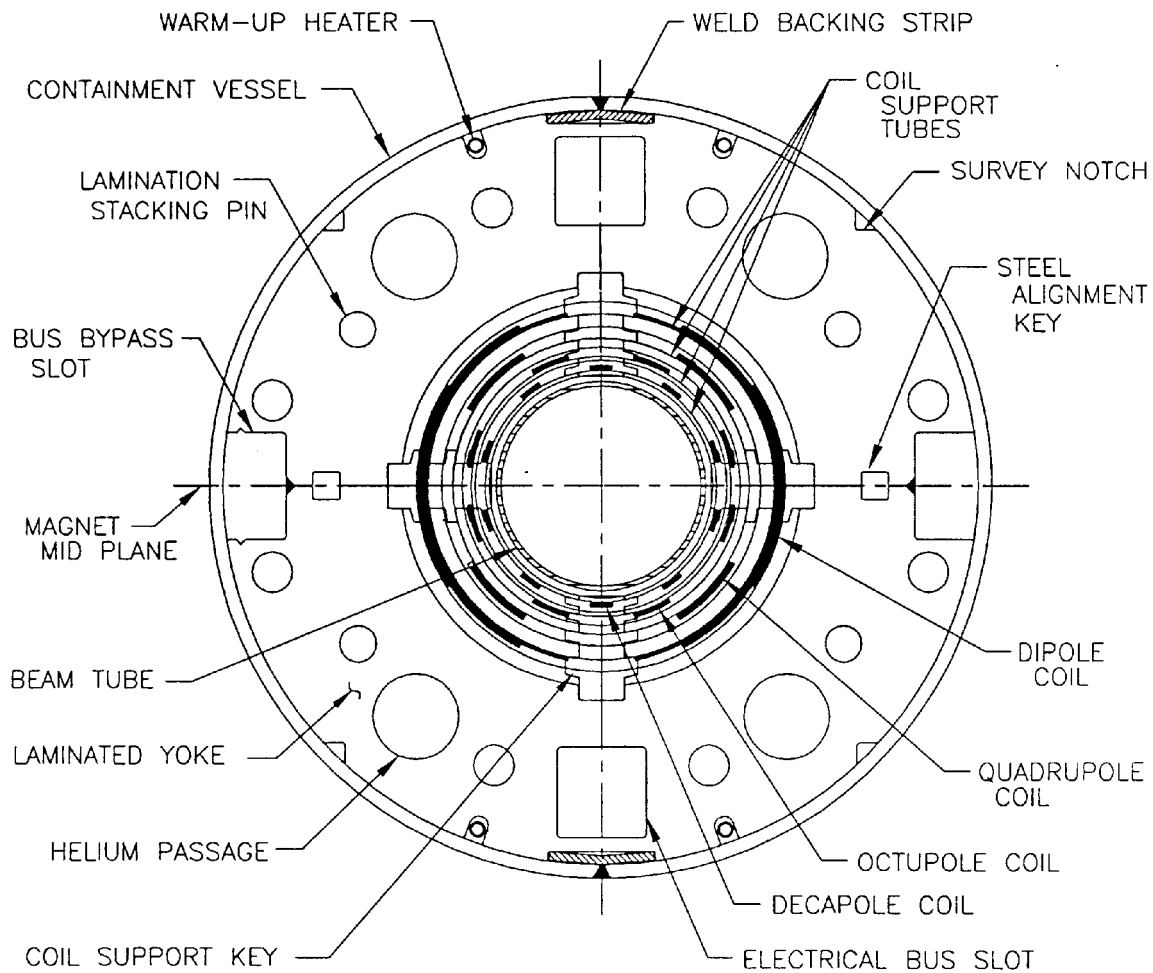


Fig. 1-10. Arc corrector cross-section (beam tube i.d. = 69 mm).

developed technology which incorporates the MULTIWIRED process. Subsequently, the substrate is epoxy-bonded to a stainless steel support tube which is previously wrapped with Kapton and fitted with aluminum locating pins. The wire is a multifilamentary NbTi composite wire, the parameters of which are given in Table 1-6.

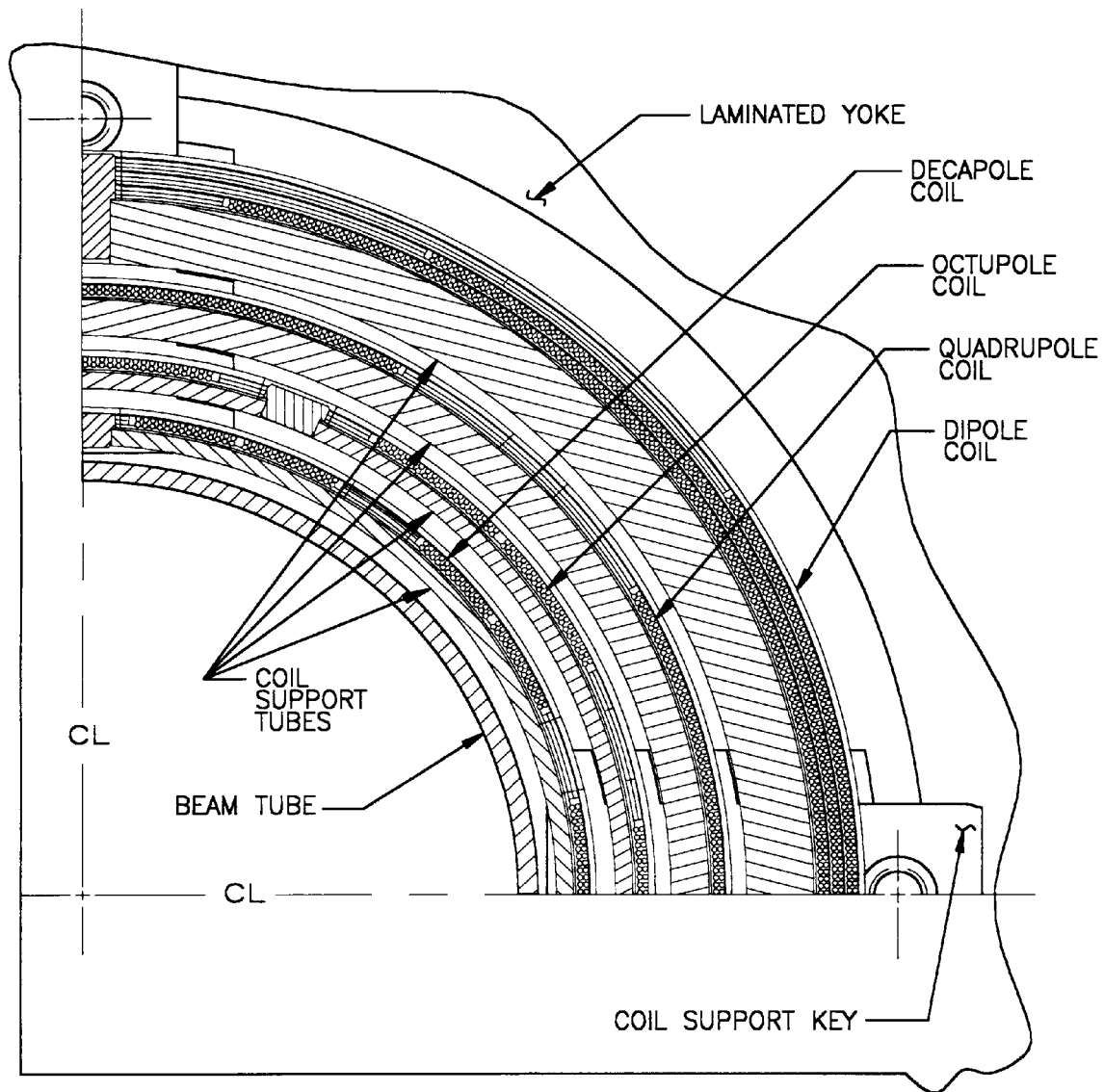


Fig. 1-11. Arc corrector coil cross-section (beam tube i.d. = 69 mm).

Table 1-19. Standard-Aperture Corrector Magnets

Number of correctors, arc and Q9	300
Number of insertion correctors	120
Effective length, nominal*	~0.5 m
Coil length, nominal*	(~23 in.) ~580 mm
Wire diameter (0.013 in.)	0.33 mm
Length, lamination	(26.50 in.) 0.673 m
Outer diameter	(10.50 in.) 266.7 m
Weight of steel	(430 lb) 195 kg
Lamination thickness	(0.0598 in.) 1.519 mm
Number of cooling channels	4
Diameter of cooling channels	(1.187 in.) 30.15 mm
Bus cavity width, height	(1.25 in.) 31.75 mm

*For exact values see Tables 1-20 and 1-21.

The beam tube fits loosely within the bore of the decapole coil support tube. It is actually the end portion of a continuous beam tube for the corrector-sextupole-quadrupole (CQS) package. It is fixed at one end to a beam position monitor located near the far end of the sextupole magnet; the other end of the beam tube is secured outside the end of the corrector magnet.

The major standard-aperture corrector design parameters are given in Table I-19. The physical length of the various coils is nominally 0.58 m, a length short enough that the stainless steel support tubes can be supported solely at their ends. The tube diameters were selected from commercially available standard size to minimize machining. The dipole and quadrupole support tube thicknesses were chosen to give acceptable distortions due to the predicted magnetic forces, and the octupole and decapole support tube thicknesses were determined by machining requirements. The end support is provided by separators, four at each end, which serve to position the tubes radially, azimuthally, and axially, and which tie into the overall corrector/quadrupole/sextupole support and alignment structures.

Table 1-20. Mechanical Parameters of Arc Correctors coils. All coils are double layers.

Multipole	Support tube o.d. ((in.)/mm)	Turns/Pole	Overall length ((in.)/m)	Wire length (m)
Decapole	(3.231) 82.1	28	(22.980) 0.584	306
Octupole	(3.624) 92.0	38	(22.962) 0.583	359
Quadrupole	(4.126) 104.8	90	(23.016) 0.585	426
Dipole/1	(4.824) 122.5	278	(22.850) 0.580	660
Dipole/2		226		544
Dipole/3		122		307

The yoke laminations are stamped from 1.5 mm thick low-carbon steel sheet. They have the same external configuration as the quadrupole laminations. Assembly and alignment is as described for the arc quadrupole, with which the sextupole and corrector share a common support structure and helium containment vessel.

A summary of the arc corrector coil parameters required for each multipole is given in Table 1-20, and Table 1-21 gives the operating parameters of the corrector magnets. In general, all the correctors are designed to operate conservatively at ~25-33% of their quench limit.

Table 1-21. Operating Parameters of Arc Correctors

Multipole	Inductance (mH)	I_{op} (A)	B @ 2.5 cm (T)	L_{eff} (m)	I_Q (A)
Decapole	5.0	59.0	0.016	0.575	202
Octupole	8.0	50.6	0.017	0.571	198
Quadrupole	29.0	49.8	0.067	0.555	190
Dipole	840	52.2	0.596	0.508	160

Large Aperture Correctors

Triplets of large bore, i.e. 13 cm, quadrupoles will be antisymmetrically placed on either side of all six intersection points of RHIC. In RHIC collision optics, the triplets at the two experimental detectors are intended to enable the collision beta function to be reduced to the design goal of $\beta^* = 1$ m in both planes, in order to minimize the spot size and maximize the luminosity. This requires running with $\beta_{MAX} \approx 1400$ m in the triplet, where the beams will have their largest size, both absolutely and as a fraction of the available aperture. Hence, the ultimate performance of RHIC rests on achieving the highest possible magnetic field quality in the triplets. The correction of magnetic errors expected in the quadrupole bodies and ends will be attempted by quadrupole body tuning shims, and by lumped correctors.

The large aperture triplet of quadrupoles Q1, Q2 and Q3 on each side of each crossover have associated with them three correctors, for a total of 36 correctors per ring. One, here called C1, is at the crossover end of Q2, a second, C2 is at the crossover end of Q3 and a third, C3 is at the other end of Q3. All have 4 corrector elements in the following combinations, with numbers given for two rings:

- Style I: b_0, b_3, b_4, b_5 @ 12 C1 Outer
- Style J: a_0, b_3, b_4, b_5 @ 12 C1 Inner
- Style K: a_1, a_3, a_2, a_5 @ 24 C2 Inner & Outer
- Style L: b_0, b_3, b_2, b_5 @ 12 C3 Inner
- Style M: a_0, b_3, b_2, b_5 @ 12 C3 Outer

Table 1-22. Properties of Large Aperture Correctors

Parameter	a_0/b_0	a_1	a_2/b_2	a_3/b_3	b_4	a_5/b_5
Number	48	24	48	72	24	72
Layers	6	2	2	2	2	2
R outer (mm)	97	95	76	82	76	69
R inner (mm)	93	93	73.5	80	73.5	67
Turns/coil/layer	149	79	41	33	23	17
$\int B \cdot ds$ (T·m)*	0.285	44.6×10^{-3}	20.6×10^{-3}	8.64×10^{-3}	5.19×10^{-3}	4.12×10^{-3}
L (mH)	1710	112	30	26	14	8.6

*@ $R_{\text{ref}} = 40$ mm and $I = 50$ A.

The nominal magnetic length of these correctors is 0.5 m and each element will have a nominal operating current of 50 A. The iron lamination inner diameter is 200 mm; the overall o.d. is 350 mm. These correctors will use the same type of double-layer multiwire coils used in the arc correctors. Table 1-22 shows the winding packages for each corrector element and other salient parameters.